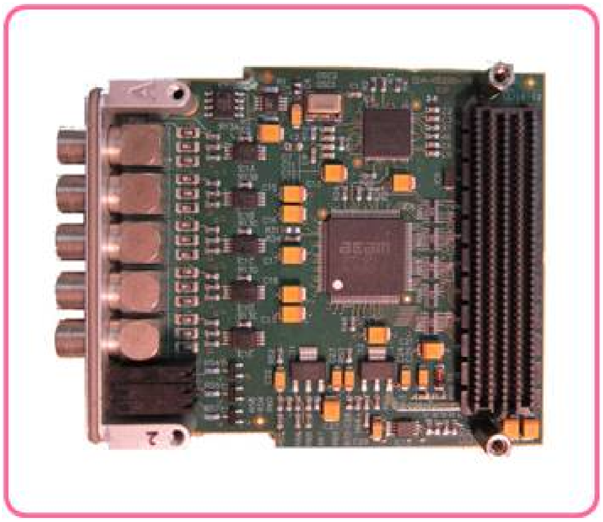
TDC Calibration

User Guide



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Introduction 1

Welcome to the Calibration procedure guide for TDC boards! A TDC board should have successfully passed the TDC PTS testing, before its calibration. Similarly to the TDC PTS, for the TDC Calibration the same PTS environment is used.

On the other hand, the SPEC-Fine Delay combination that is used in the TDC PTS, is now replaced by a Pendulum and a Pulse Distributor unit. Figure 1 shows the main elements of the TDC Calibration, whereas Table 1 is listing them in detail.

Figure 1: TDC PTS Calibration view

Item	Comments
Computer	power cable provided
Monitor	not provided
Keyboard, Mouse	not provided
Barcode reader	USB cable provided
ESD strap	
PCIe Extender cable	
SPEC board	screws for mounting the TDC mezzanine on provided
Pendulum CNT-91	USB and power cables provided
Timetech Pulse Distributor	power cable provided
USB interconnection box	USB cable provided
1x BNC-SMA cable	BNC cable, of any length, with SMA connector on one side
2x BNC-LEMO cables	Each of these two cables is composed of: 1 BNC cable, 1 LEMO cable, 1 BNC-to-LEMO converter. The two BNC cables are of identical length; one of the LEMO cables is 8ns and the other 2ns.
4x LEMO cables	of identical length, 1ns
Documentation	this user guide plus a one-page testing procedure

Table 1: TDC-PTS-Calibration elements

A TDC mezzanine board is calibrated while mounted on a SPEC carrier board, as figure 2 shows. The SPEC carrier board provides access to the PCIe interface of the computer. The computer hosts the TDC-PTS-Calibration software which provides the automated testing environment.

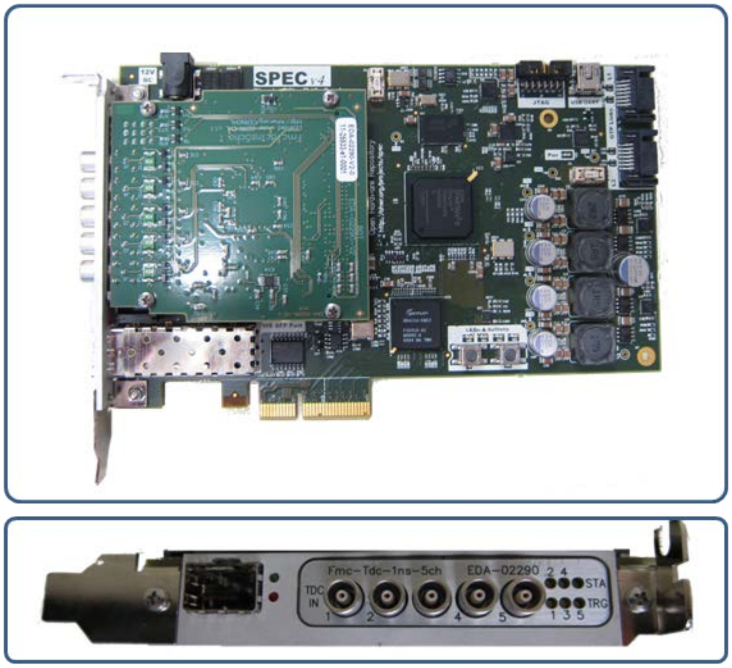


Figure 2: SPEC-TDC combination

To facilitate the testing setup, a PCIe extender cable is provided.

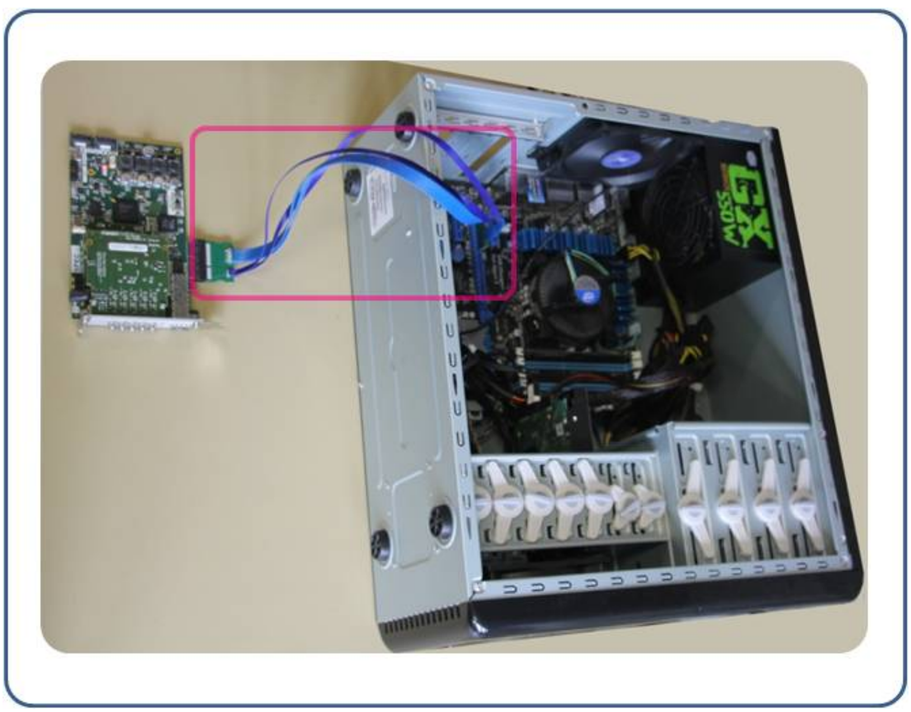


Figure 3: PCIe extender cable

The Pendulum CNT-91 is used as pulse generator for the testing. It is controlled through USB from the TDC-PTS-Calibration software.

The Timetech Pulse Distributor is receiving the Pendulum output and makes it available simultaneously to two of its output channels.

Figure 4: Pendulum CNT-91 (left), Timetech Pulse Distributor (middle) and USB-interconnection-box (right)

The USB-interconnection-box is receiving the two Timetech Pulse Distributor outputs and makes them available to two of the TDC input channels at a time. It is controlled through USB by the TDC-PTS-Calibration software. Note that the USB-interconnection-box should itself be calibrated! Confirm that the “calibrated” sticker is on the box, before using it.

A BNC-SMA cable is used to connect the Pendulum to the Timetech Pulse Distributor input.

To connect the two Timetech Pulse Distributor outputs to the USB-interconnection-box two special cables are provided, each consisted of a BNC cable, a BNC-to-LEMO converter and a LEMO cable. The BNC cables are of identical length, whereas one of the LEMO cables is 8ns long and the other 2ns.

Finally, a set of five 1ns LEMO cables is provided for the connections between the five outputs of the USB-interconnection-box and the five TDC input channels.

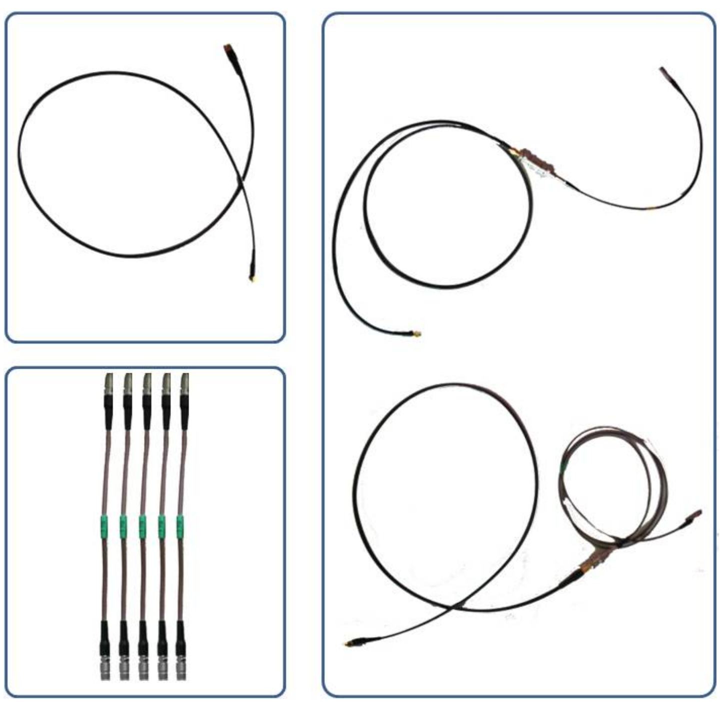


Figure 5: 1x BNC-SMA(top left), 5x LEMO(bottom left) and 2x special-BNC-LEMO(right) cables

In terms of software, the computer is equipped with the following:

- Ubuntu Linux, with kernel 2.6.38 or higher
- Python 2.7
- The PTS environment installed
- Driver gnurabbit installed

The user login is the following:

- Username: user
- Password: baraka

The computer should not be connected to the network and no updates should be allowed.

The duration of the test of a TDC board is twelve minutes.

Briefly, the operator needs to:

- mount the TDCboard on the **SPEC carrier**
- Plug the SPEC-TDC combination on the **PCIe** extender cable
- connect the five LEMO **cables** between the TDC and the **USB-interconnection-box**
- run the **software**

At the end of the test the operator receives a PASS/FAIL notification. In case of a FAILED board, information is provided on the failing components.

All test results are automatically saved in a folder on the computer.

For a FAILED board, you can repeat the test only one more time! If a board FAILs twice, please report to the CERN responsible.

TDC Board Calibration 2

The Time to Digital Converter board, TDC (EDA-02290) is an FMC mezzanine board with five input channels. It houses the Time to Digital Converter chip ACAM and it can calculate time differences between pulses arriving on the different channels.

The track length from an input to the ACAM chip differs from channel to channel; in addition the input logic (clock buffers) of each channel is introducing different delays that can vary up to 2ns. That is why it is essential to calibrate the TDC board channels. Refer to the channels calibration document for more information.

Moreover the main timekeeping unit of the board needs to be calibrated. The DAC IC2 on the board controls the OSC2 voltage-controlled-oscillator which in turn controls the PLL IC6. Alterations on the DAC voltage change slightly the frequency of the pulses coming out of the PLL and therefore the timestamp measurements. For example, a pulse period of 9 ms can be measured as 8.999967000 ms with the DAC at 1.25V and as 9.000000300 ms with the DAC at 1.65V. Note also that the VCXO OSC2 is strongly influenced by temperature changes; the documentation specifies 0.5ppm/oC. Refer to the DAC calibration document for more information. The DAC is controlled through an SPI interface.

The TDC-PTS-Calibration software is also responsible for writing the calibration data along with IPMI information in the TDC EEPROM.

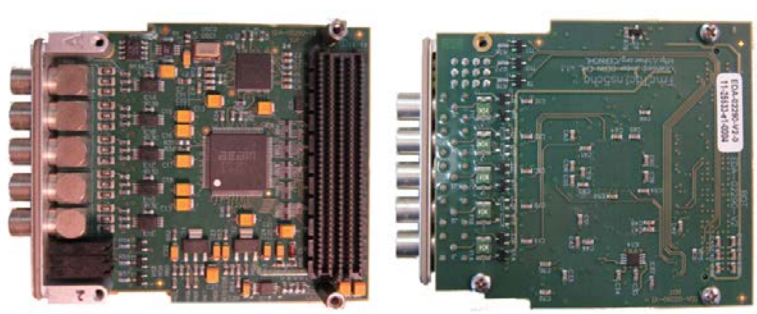


Figure 6: Top, bottom and front views of the TDC board

Figure 7 shows the main parts of the board.

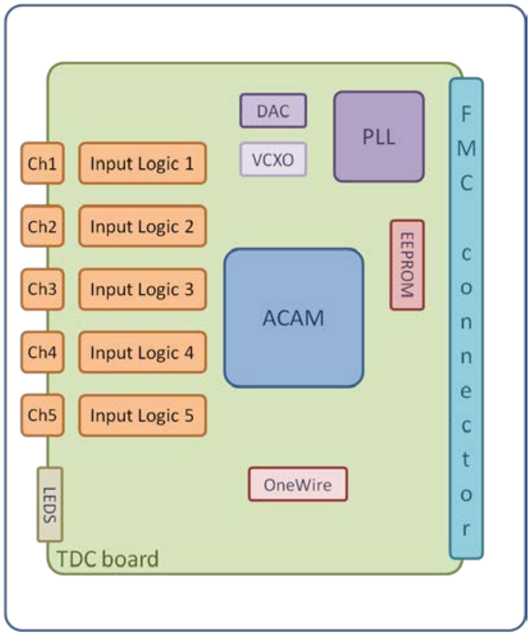


Figure 7: Basic parts of the TDC board

The following picture shows in detail the location of the aforementioned components.

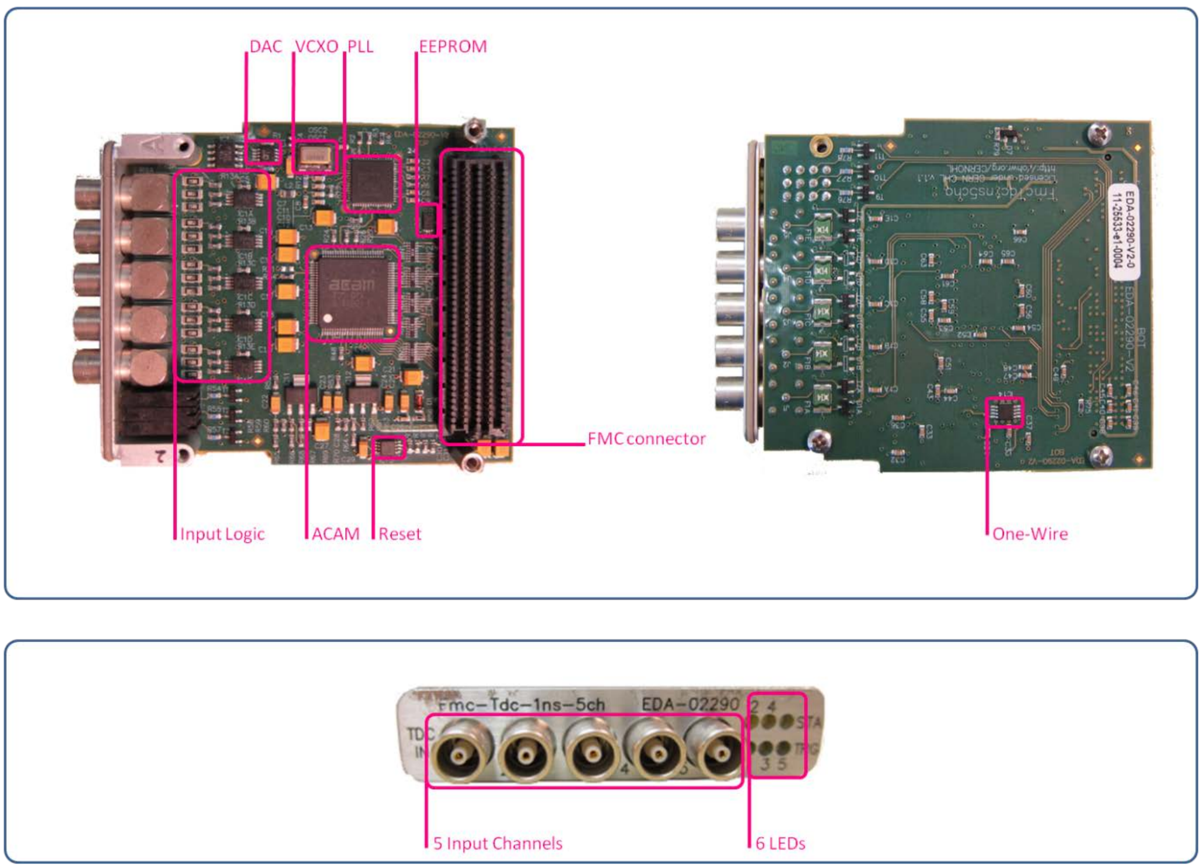


Figure 8: TDC main components

The TDC mezzanine board is tested while mounted on a SPEC carrier board. The SPEC provides FPGA logic, power supplies, memories, clocking resources and interface to the PCIe bus.

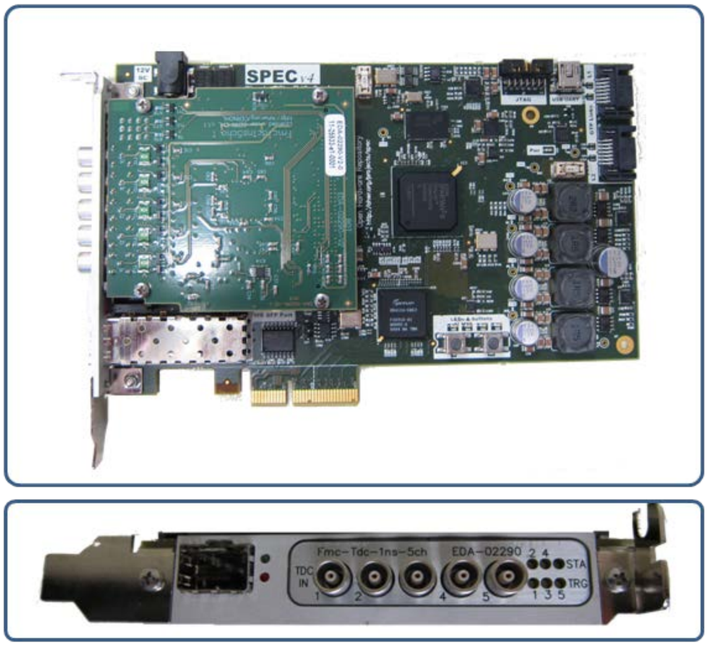


Figure 9: SPEC-TDC combination

PTS Calibration Software 3

The dedicated software running on the PTS computer provides the automated test environment.

The software automatically initiates a sequence of 4 tests. A TDC board calibration is considered “PASSED” if it has successfully “PASSED” all the 4 tests. If a test fails, the software continues with the following tests and the operator is informed at the end of all the failing parts. Table 2 lists the different tests.

Test	Short Description	Operator's Intervention
00	Channels calibration	YES, swap of two cables
01	DAC calibration	NO
02	EEPROM writing	NO
03	Calibration verification	NO

Table 2: List of tests

Log files retrieval 4

Log files holding all the information about the testing of a board are automatically generated and saved by the software at the location: **/home/user/pts/log_fmctdc1ns5cha_calib**

For each test run, a .zip containing one file per test is created under the name: zip_run_<runid>_<timestamp>_FmcTDC1ns5cha_<serial number>.zip.

Once the testing of all the boards has finished, the log files would need to be delivered to CERN. To do so, please follow the instructions:

- Plug a USB memory key on the computer
- Wait until Ubuntu mounts automatically the device and use the file explorer to navigate to /home/user/pts/log_fmctdc1ns5cha_calib
- Select all the .zip files in this folder and copy them to the USB memory
- Use another computer with Internet access
- Send the files from the USB memory to the CERN responsible by email

First Time Setup 5

1) Make sure that the computer is switched off. Plug the barcode-reader into one available USB slot of the computer.
2) Connect the monitor, keyboard and mouse to the computer.
3) Plug the ESD strap in the yellow socket of the computer box.
4) Screw the SMA side of the BNC-SMA cable to the “Pulse Out TTL levels in 50Ω” plug of the Pendulum. Plug a USB cable from the Pendulum to any USB slot of the computer.

   Connect a 220V power cord to the Pendulum and switch it ON.

Figure 10: Pendulum with USB and “Pulse Out” connections

5) Screw the other side of the BNC-SMA cable to the Timetech Pulse Distributor input “IN B”.

   Screw any of the two special BNC-LEMO cables to “OUT 1” of the Timetech Pulse Distributor; screw the other special BNC-LEMO cable to “OUT 2”.

   Connect a 220V power cord to the Timetech Pulse Distributor and switch it ON.

Figure 11: Pulse Distributor with “IN B”, “OUT 1” and “OUT 2” connections

6) Connect any of the two special BNC-LEMO cables to “SOURCE 1” of the USB-interconnect box; connect the other special BNC-LEMO cable to “SOURCE 2”.

   Plug a USB cable from the USB-interconnect box to any USB slot of the computer.

   Connect the five 1ns LEMO cables to the “CH[1..5]” outputs of the USB-interconnect box.

Figure 12: USB-interconnection-box front (USB, 2xLEMO) and back side (5xLEMO)

7) Make sure that the computer is switched off and plug the PCIe extender cable into the computer slot indicated in Figure 10.

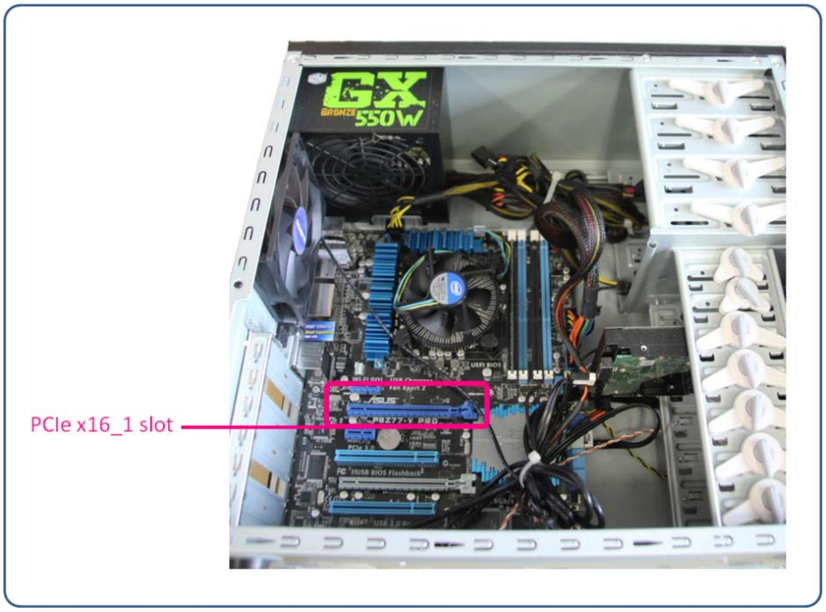
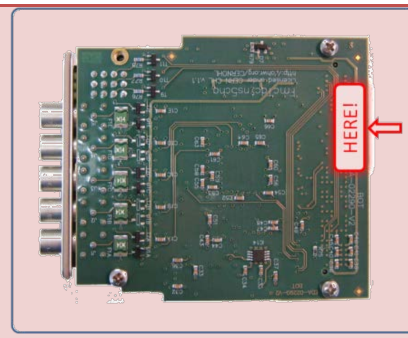


Figure 13: PCIe slot for the extender cable

6 Testing Procedure

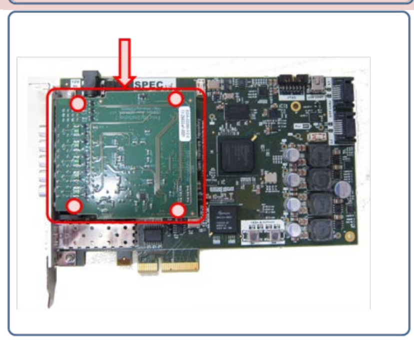
1) Place the **ESD strap** on your wrist.

2) Confirm that the TDC board under test is identified with a **barcode sticker** on its Bottom side.

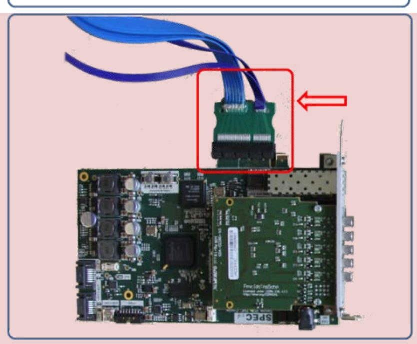


3) Mount the TDC board on the **SPEC board**.

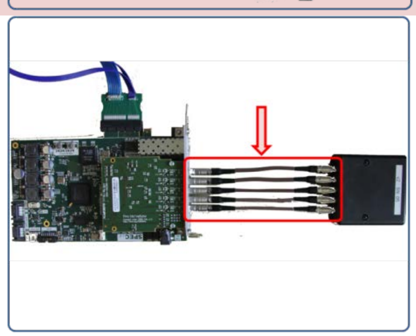
   Fix using the provided **screws**.



4) Plug the SPEC-TDC combination on the **extender cable**.



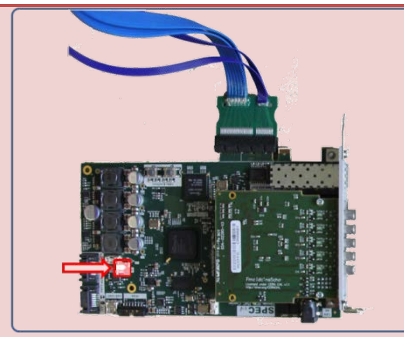
5) Plug the **LEMO cables** between the five USB-interconnection-box outputs and the five TDC inputs, as the figure shows.



6) Switch **ON** the **computer**.

Verify that the “Pwr” LED on the SPEC board is ON. This will confirm that the SPEC board is properly plugged.

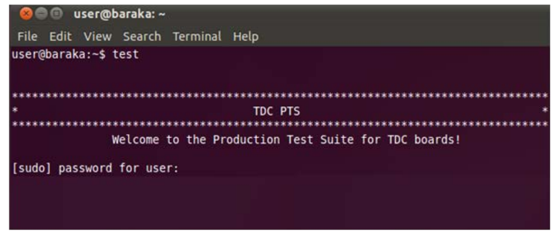
If the LED is OFF there is a problem with the power supply lines.



7) After the computer has finished with the booting procedure, a **terminal** appears automatically in the middle of the screen.

Type “**calib**” and then [ENTER] to start the test program.

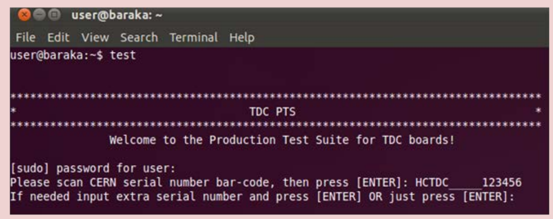
When asked, type the password: “**baraka**” and [ENTER]



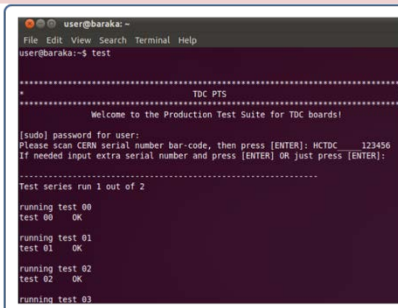
8) The program asks for the **barcode** of the board.

Check that the cursor is on the terminal,
press the barcode reader’s button.
The barcode will appear on the terminal. Press [ENTER].

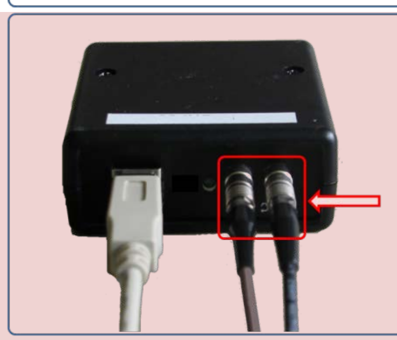
The program will ask for a second barcode, in case the manufacturer has a different serial number system.
Scan the second barcode and press [ENTER],
or if there is none, just press [ENTER].



9) The program will automatically **execute tests 00 to 03**.



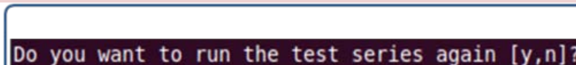
10) Test 00 requires the operator’s intervention. When prompted, the operator needs to swap the USB-calibration-box Source inputs.



11) At the end the operator is informed of the **results** of all the tests and is asked if he wants to repeat the test.

If no error had occurred, type [n] and then [ENTER].

In case of error, you could repeat the tests once by typing [y] and [ENTER].



If you need to repeat the tests more than two times for one board, please report to the CERN responsible.

Common Causes of Test Failure 7

Once the testing has finished, all the errors that may have appeared are listed on the screen. The log files, located at **/home/user/pts/log_fmctdc1ns5cha_calib** also hold all the details of the testing. The error messages are in principle self explanatory giving clear indication of the failure, however for more insight information on the testing procedure and the common causes of failure you could consult the following sections.

Test 00: Channels Calibration

Test for the calibration of the input channels. The aim of the test is to calculate the path differences (in ps) of each TDC channel with respect to the reference channel 1. he test is using the Pendulum CNT-91 as pulse generator sending pulses with a period of 1 ms. The USB-interconnection-box is configured to redirect the pulses to one TDC channel pair at a time: [channel 1, channel 2], [channel 1, channel 3], [channel 1, channel 4], [channel 1, channel 5]. For every pair, 12’800 rising edge timestamps coming from the TDC channel 1 and 12’800 rising edge timestamps coming from the TDC pair channel are accumulated. The timestamps are subtracted in order to calculate the average path difference between the two channels. In order to compensate for the delays introduced by the cabling, the operator is asked to swap the USB-interconnection-box input cables and the same measurements are repeated. Finally the four calibration values are written in a file.

Possible reasons of failure:

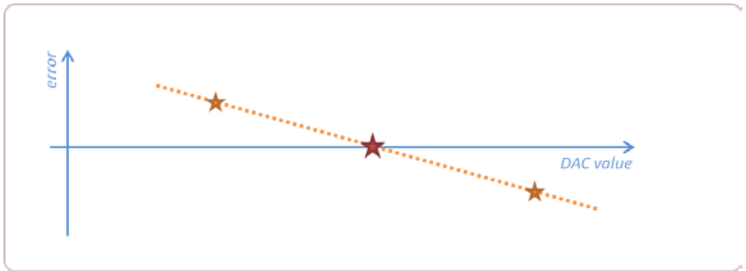
- Bad connections between the Pendulum and the Pulse Distributor
- Bad connections between the Pulse Distributor and the USB-interconnections-box
- Bad connections between the USB-interconnections-box and the TDC channels
- Bad connections between the SPEC and the TDC

Test 01: DAC Calibration

Test for the calibration of the TDC DAC IC2 that controls the VCXO OSC2 which in turn controls the main timekeeping unit of the TDC application, the PLL IC4. The test is using the pendulum CNT-91 as pulse generator sending pulses with a period of 5 ms. As described in chapter 2, the higher the DAC value, the higher the TDC is measuring the pulse period; for example with the DAC at 1.25V the TDC measures the 5 ms period as 4,999967682 ms, whereas with the DAC at 1.65V the TDC measures the 5 ms period as 5,000000309 ms. The test:

1) waits for a relative stabilization of the board’s temperature
2) implements a bisectomy algorithm to find a first DAC value that brings the measurements close to the expected 5 ms; to keep this step short in time, for each DAC value only 64 measurements are acquired and averaged.
3) once this first rough idea of the location of the optimal DAC value is acquired, the test continues with focusing on two values around it; in this case, in order to stay intact from the +-700ps imprecision of the TDC, 12’800 measurements and averaged.

4) with these two last values a line is defined, as the following figure shows; the final optimal DAC value is considered to be the one where this line is crossing the x-axis.



5) this DAC value along with a temperature measurement are written in a file.

Possible reasons of failure:

- Bad connections between the Pendulum and the Pulse Distributor
- Bad connections between the Pulse Distributor and the USB-interconnections-box
- Bad connections between the USB-interconnections-box and the TDC channels
- Bad connections between the SPEC and the TDC

Test 02: EEPROM writing

Test for the writing of the TDC EEPROM with IPMI and the calibration data. The test is reading the files generated by the tests 00 and 01 and also generates the IPMI data. The data is transferred to the EEPROM through its I2C interface and then all the data is read back for confirmation.

Possible reasons of failure:

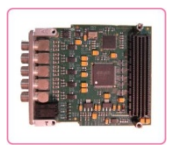
- Failures on the previous tests

Test 03: Calibration Verification

Test for the verification of the calibration procedure and EEPROM writing. The test is reading the EEPROM and extracts the DAC calibration and the channels calibration values. The Pendulum is sending pulses of 5 ms period. A similar procedure to the one of the tests 00 and 01 is used for the evaluation of the calibration. In this test, no user intervention is essential.

Possible reasons of failure:

- Bad connections between the Pendulum and the Pulse Distributor
- Bad connections between the Pulse Distributor and the USB-interconnections-box
- Bad connections between the USB-interconnections-box and the TDC channels
- Failures on the previous tests



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